Crescendo Millennium Edition

remake of a famous amplifier

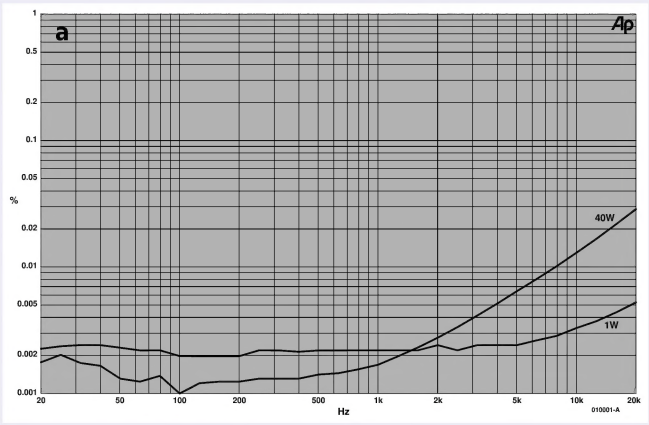
Design by T. Giesberts

In early 1984, Elektor magazine beat the competition hands-down by publishing the design of a then-revolutionary MOSFET amplifier. Even now, this amplifier enjoys an enthusiastic following. In response to many requests, we have brought the design up to date and given some attention to improved reliability and operating safety. The output power is 90 watts into 8 ohms or 135 watts into 4 ohms, which should leave little to be desired for most users.

Measured results

(power supply as shown in Figure 3; quiescent current 200 mA)

– input sensitivity:		$1\ V_{rms}$	
– input impedance:		45 kΩ	
– sine-wave power (0.1 % THD):		90 W/8 Ω, 137 W/4 Ω	
– power bandwidth (80 W/8 Ω):		1.5 Hz – 300 kHz	
– slew rate:		60 V/µs (rise time = 1µs)	
– signal/noise ratio:		104 dB (A-weighted)	
(with respect to 1 W/8 Ω)		96 dB (BW = 22 kHz, linear)	
– harmonic distortion		at 8 Ω:	at 4 Ω:
(bandwidth 80 kHz):	at 1 kHz:	0.002 % (1 W)	0.0026 % (1 W)
		0.0017 (40 W)	0.004 % (80 W)
	at 20 kHz:	0.028 % (40 W)	0.04 % (80 W)
– intermodulation distortion:		0.0017 % (1 W)	0.003 % (1 W)
(50 Hz : 7 kHz = 4 : 1)		0.004 % (40 W)	0.007 % (80 W)
– dynamic IM distortion:		0.0026 % (1 W)	0.003 % (1 W)
(3.15 kHz square wave with		0.0014 % (40 W)	0.0023 % (80 W)
15 kHz sine wave)			
– damping factor (at 8 Ω):		460 (1 kHz)	
		330 (20 kHz)	
– open-loop parameters:			
gain:		4,000	
bandwidth:		25 kHz	
output impedance:		0.5 Ω	
protection:			
DC:		+ 4.7 V / – 4.3 V	
overload (0 V out):		+ 5.8 A / –5.4 A	
switch-on delay:		8 to 10 s	
bias compensation:		± 4.5 µA	



From the number of zeros after the decimal point, you can see in a single glance that this is an exemplary set of results. You will not often come across a better set of figures. The distortion is very low, the damping factor is very good and the slew rate can even be said to be remarkably good.

As you may expect, we have also measured a number of curves using the Audio Precision analyser in order to complement the performance figures, which always have a somewhat 'dry' taste.

Figure A shows the harmonic distortion (THD+N) over the range of 20 Hz to 20 kHz with an 8-Ω load, using a measurement bandwidth of 80 kHz. At 1 W the increase in the distortion level at 20 kHz is minimal, but at the 50% power level (40 W is equivalent to 70% of the maximum output amplitude) the effect of the non-linear input capacitance of the MOSFETs can be recognised.

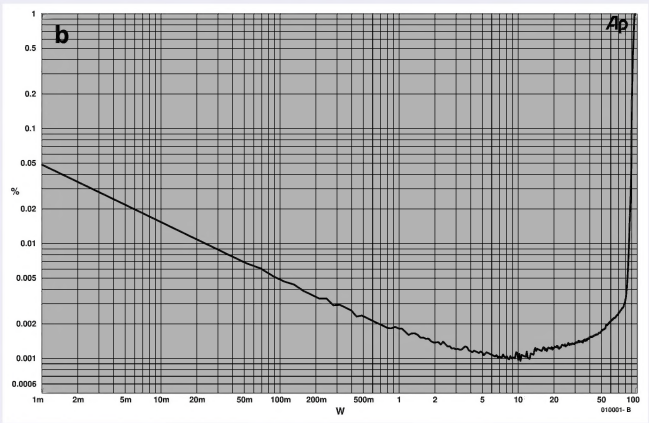
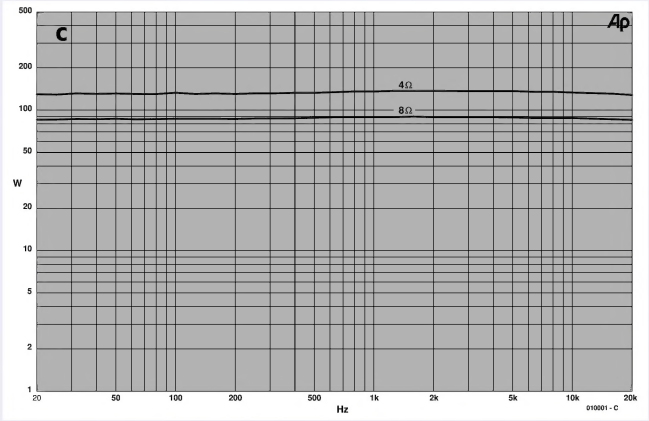


Figure B shows the distortion of a 1-kHz signal into an 8-Ω load as a function of the output level in watts, measured with a bandwidth of 22 kHz. The behaviour of the amplifier is more readily visible with this narrower measurement bandwidth. Up to 10 W, the THD+N is predominantly due to supply ripple and noise. A slight increase in the distortion can be seen above 10 W, but a level of 0.1% is reached only at 90 W.

Figure C shows the maximum output power into 4-Ω and 8-Ω loads at a distortion level of 0.1% for frequencies between 20 Hz and 20 kHz (80 kHz measurement bandwidth). Both of these curves can be said to be practically straight.



Finally, Figure D shows the results of a Fourier analysis of a 1-kHz signal (1 W into 8 Ω) with the fundamental suppressed. At this power level, the THD is clearly lower than the supply ripple, whose harmonics lie below –100 dB. The 2nd and 3rd harmonics lie at negligibly low levels (–118 dB and –115 dB, respectively).

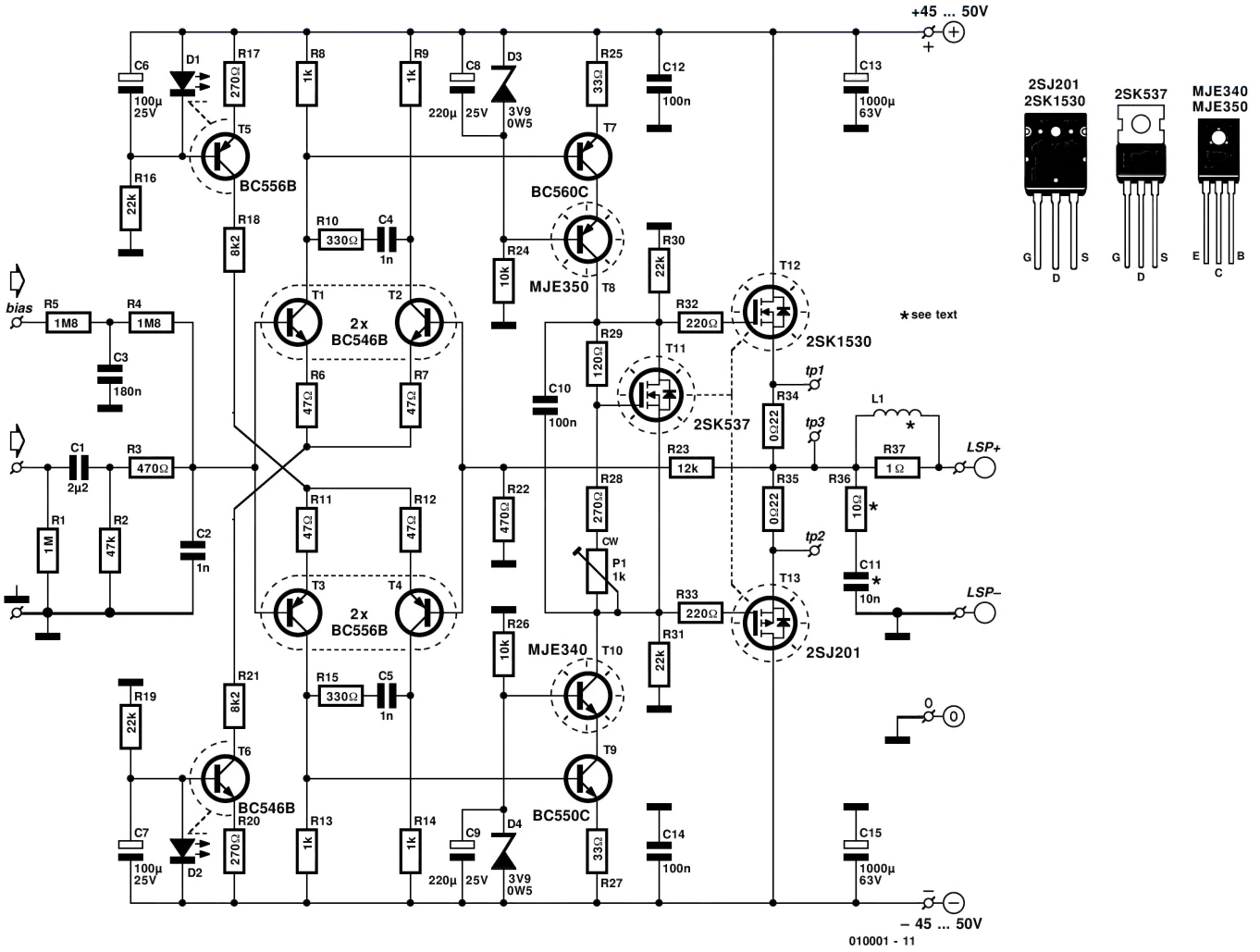


Figure 1. In the schematic diagram, the changes from the original version are hardly noticeable at first glance.

There are surely not very many circuit designs that continue to enjoy such a high level of interest more than ten years after their original appearance, as does the Crescendo power amplifier from 1984. In part, this is due to its completely symmetrical design, which was in fact an unusual feature at that time, but unquestionably it is mainly due to the use of power MOSFETs in the output stage. A lot of people happen to be fervent fans of these devices. Even people who swear by valve amplifiers and are allergic to anything with 'semiconductor' in its name often have a weakness for MOSFETs, and are thus prepared to make an exception for them. Sadly enough, most of the problems with the amplifier in question had to do with the MOSFETs. The original types have long since gone obsolete and become unavailable, and suitable replacements are hard to find. However, there were also other difficulties. The stability of the amplifier sometimes gave cause for concern, and users considered the absence of protective circuitry to be a major weakness.

Consequently, in honour of our anniversary, we decided to take another look at the original design. Our objective was to update the design of the amplifier in a way that would eliminate the sources of criticism without sacrificing the good characteristics of the original design. This objective has been quite successfully achieved. In addition, we were able to obtain such a generous level of output power using a new pair of MOSFETs that it is not necessary to split the new Crescendo into 'light' and 'heavy' versions.

The same concept

Since we have intentionally tried to change the old amplifier design as little as possible, the differences between the schematic diagrams of the old and new versions are minimal. The design still consists of an input stage with dual differential amplifiers and current sources, a cascode driver stage and a MOSFET output stage. That may have been a rather sophisticated design in 1984, but nowadays it would more likely be described as a 'minimal design'. There's nothing wrong with this, by the way, since attempting to keep the signal path as short as possible is certainly not a mistaken endeavour in an amplifier design — but we don't need to dwell on this point.

Since the basic concept of the original design has been retained, anyone who compares the schematic diagram of the new version (**see Figure 1**) with that of the old version (May 1984) will first have to try to find the differences. Of course, there

are indeed differences, and it seems like a good idea to list the most important changes before diving into a detailed description of the schematic diagram.

The most evident change is naturally the new pair of MOSFETs in the output stage. The Toshiba 2SK1530 and 2SJ 201 are readily available, and furthermore they can dissipate so much more power than the original devices that we were able to boost the output power of the old 'Mini-Crescendo' by a factor of nearly two (90 W into 8 Ω in place of 50 W) using only a single pair of transistors.

As a consequence of the increased power level, the bias currents of the various stages must be modified and different transistors must be used in the cascode stage, as will be seen later on.

The next change is the addition of the networks R10/C4, R15/C5 and R30/R31, which represent the results of measures that have been taken to optimise the stability of the amplifier. A very important final item is that the amplifier has been provided with reliable protection circuitry and automatic offset compensation, by means of an extra printed circuit board.

This pretty well covers the most important changes.

Schematic details

Now that we've seen the global picture, it's time to take a more detailed look at the circuit diagram. Let's start at the beginning, which is of course the input stage.

The design of the input filter is more or less standard. R2 (with R1 in parallel) determines the input impedance, and in combination with C1 it forms a high-pass filter that blocks frequencies below around 1.5 Hz. C1 is also needed to isolate the DC bias of the input stage. The combination of R3 and C2 forms a low-pass filter that is dimensioned for a frequency of more than 300 kHz. This helps prevent TIM (transient intermodulation) distortion and eliminates possible RF interference.

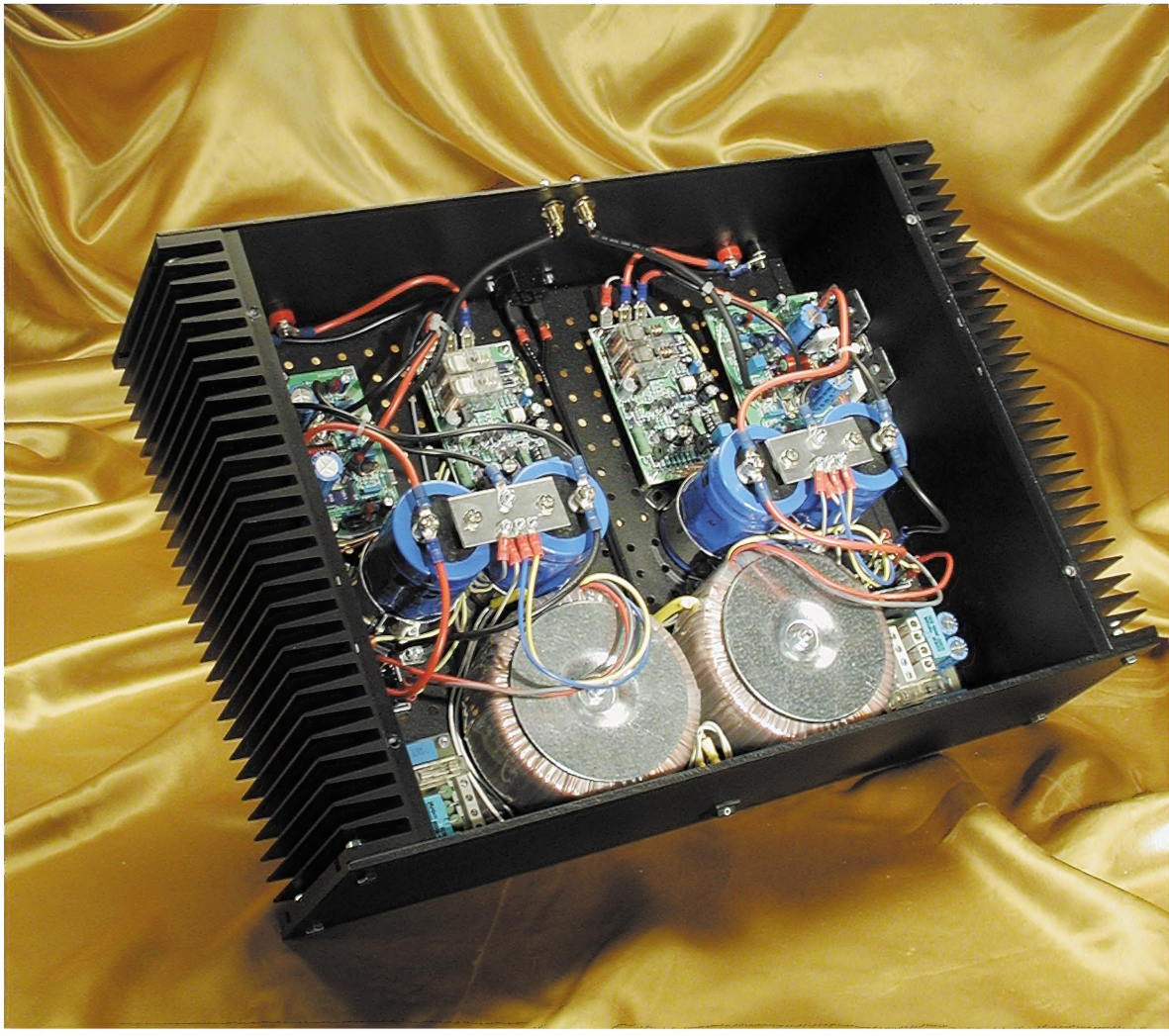
The dual differential amplifier (T1–T4) has been designed to work with a bias current that is approximately three times a great as that of the original design, on account of the increased output power. The current sources that regulate this setting, T5 and T6, now use LEDs as references (D1 and D2), since this results in less noise than using Zener diodes. In the interest of the thermal stability of the DC setting, D1/T5 and D2/T6 are thermally coupled, as are the transistor pairs T1/T2 and T3/T4.

The bias currents of the cascode stages T7/T8 and T9/T10 are also significantly greater than in the original design. Since this would be a bit too much for the transistor types used for T8 and T10 in the old version, they have been replaced by the somewhat more robust types MJE340 and MJE350.

Now we come to the output stage. In contrast to the MOSFETs used in the old version, the 2SK1530 and 2SJ 201 devices used here have a positive temperature coefficient. This means that with a constant gate-source voltage, the drain current increases with increasing temperature. This made it necessary to use a different design for the quiescent- current circuit. Here the MOSFET T11, which is mounted on the same heat sink as T8/T10 and T12/T13, provides the necessary compensation.

Finally, there are a couple of other significant items.

Insiders will notice that the none-too-attractive bipolar electrolytic capacitor has been eliminated from the reverse feedback network (R22/R23), which means that DC coupling is used here. To get rid of the resulting output offset, we have provided an automatic compensation circuit that is located on the protection circuit board. We anyhow intended to



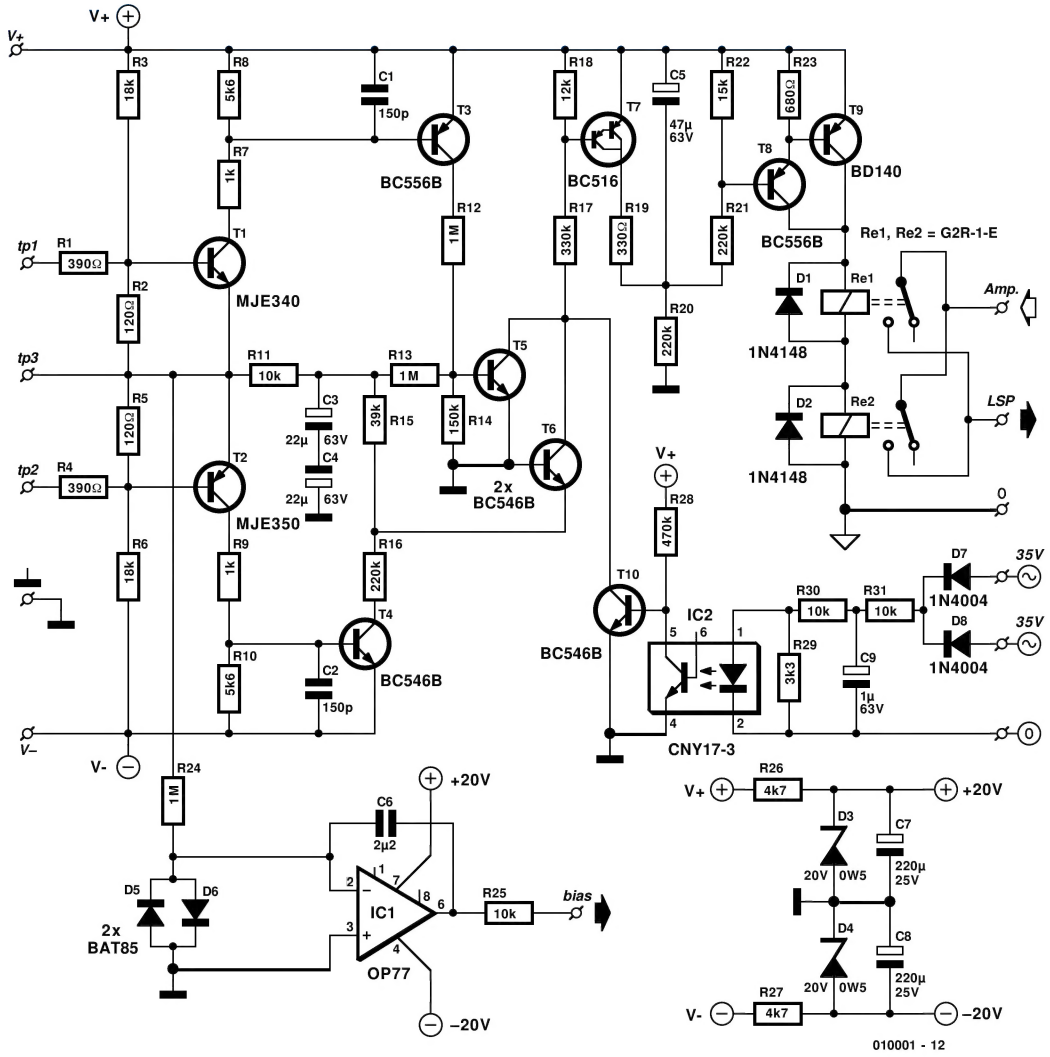


Figure 2. Schematic diagram of the added protection circuitry and offset compensation circuit.

use the compensation circuit to correct for the offset caused by the unavoidable asymmetry of the input stage. The necessary compensation circuit consists of nothing more than an opamp wired as an integrator, which measures the output voltage of the amplifier and provides the proper amount of reverse current feedback to the (bias) input. Thanks to the very high values of R4 and R5 and the decoupling provided by C3, this correction has absolutely no effect on the audio signal.

Another essential detail is that the open-loop gain has been made independent of the load by the addition of R30 and R31. These resistors together determine the output impedance of the voltage amplifier, and as a result the source followers T12 and T13 now operate purely as buffers in the audio range. Without these resistors, the behaviour of the amplifier is directly dependent on the connected load, which is not the way things are supposed to be.

Together with the compensation networks R10/C4 and R15/C5, the modification made using R30/R31 ensures that the amplifier is unconditionally stable, so much so that the standard Boucherot network (R36/C11) can even be omitted.

Protection

The protection circuitry (**Figure 2**), which is located on a separate printed circuit board, includes overload protection, DC protection, a switch-on delay for the output relay and a voltage detector that directly disables the output relay when the power is switched off or any of the transformer voltages is absent. The integrator for the offset compensation is also located on this circuit board.

There are three terminals on the power amplifier board that provide information to the protection circuitry: tp1 and tp2 convey the voltage across the emitter resistors, while tp3 conveys the output voltage. The actual protection takes place with the help of two relays (Re1 and Re2), whose switching contacts are connected in parallel in order to keep the insertion resistance as low as possible. The relay contacts are wired in series with the amplifier output via the terminals 'Amp' and 'LSP'.

The supply voltage for the protection circuitry is tapped off from the supply points on the amplifier board. The supply voltage for the integrator is simply derived from the amplifier supply voltages using a pair of Zener diodes (D3 and D4).

The **overload protection** circuit is constructed in a 'classic' manner using a voltage divider and a tran-

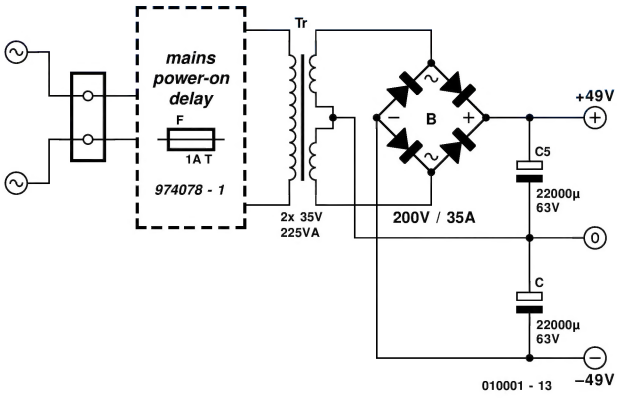


Figure 3. The power supplies of mass-produced amplifiers are rather skimpy. This one has no such problems.

sistor. T1 measures the voltage across R34 in the power amplifier circuit via the network R1-R3 and can thus determine whether the 2SK1530 has exceeded its safe operating area. The combination of T2 and R4-R6 performs the same service for the 2SJ 201 by measuring the voltage across R35. The maximum allowable current through the output transistor is linearly dependent on the voltage across the transistor, up to the point that the maximum allowable voltage or current has been reached. The maximum current limit is set using the voltage divider R1/R2 (or R4/R5 for the other half), and this limit is decreased via R3 (or R6) as the voltage across the output transistor increases. Since we can assume a music signal, we have stuck to the 100-ms limit, so that the limiting value for the load impedance can be set lower without causing problems for the output transistors. If T1 (or T2) starts to conduct, the transistors of the DC protection circuit are utilised via T3 (or T4) to disengage the relay. C1 and C2 reduce the circuit's sensitivity to HF interference. R7 and R9 are 5-W types, since their power dissipation can be significant in certain fault situations.

The **DC protection** circuitry employs a commonly used principle. Any DC voltage that is present is received via the low-pass filter R11/C3/C4 (roll-off frequency 1.5 Hz). C3 and C4 together form a bipolar electrolytic capacitor. If a sufficiently large positive voltage is present, T5 is brought into conduction via the voltage divider R13/R14, and T7 is then brought into conduction via R17. With a sufficiently large negative voltage, the current through T6 will be large enough to cause T7 to conduct. The voltage divider R13/R14, in combination with R15/R17/R18, ensures that the positive and negative threshold voltages are nearly the same. T7 can thus be brought into conduction via R12 /R16 and T5/T6. When the supply voltage comes up and no fault is present, the electrolytic capacitor C5 will be charged to approximately half of the supply voltage level via voltage divider R20/R21. The time delay before the relay engages thus amounts to around 8 to 10 seconds. Darlington T8/T10 connects the relay coils to the supply voltage. If T7 starts to conduct, C5 is immediately discharged and the relays disengage.

An optocoupler is used for the **voltage detection** circuit in order to prevent ground loops between the transformer ground and the signal ground, as well as other possible types of interference. The current for the optocoupler diode is provided by R29–R31, and the time constant determined by C9 has been chosen such that the transistor in IC2 remains continuously conducting only as long sufficient voltage is present on both transformer windings. If the voltage drops, T10 starts to conduct and the relays are disengaged.

The **offset compensation** circuit consists of only two resistors, one capacitor, an opamp (IC1) and two diodes, in addition to the supply components. Since the correction current is coupled into the non-inverting input of the power amplifier, this integrator must invert the signal. D5/D6 and R25 provide additional protection for the opamp. With an eye on protection we have chosen an OP77 (ultra-low offset) opamp, which already has internal input protection and is short-circuit proof.

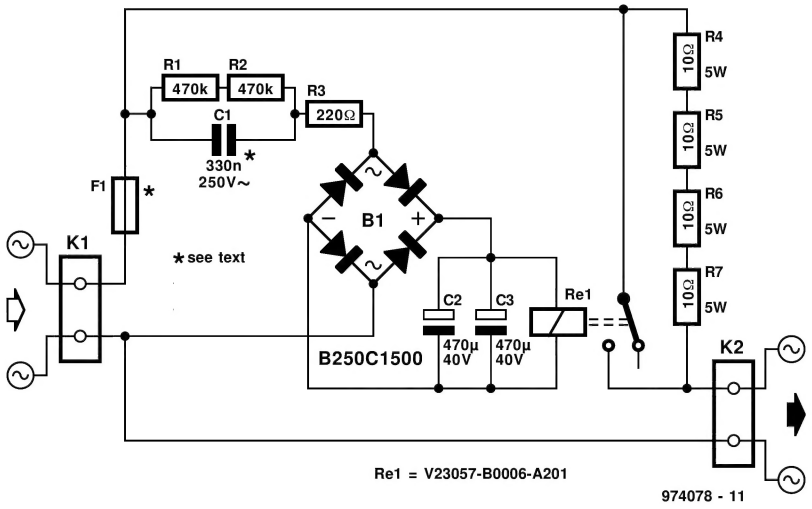


Figure 4. A mains switch-on delay circuit, such as the one shown here, prevents the fuse from blowing when the amplifier is switched on.

A robust power supply

In the description of the original Crescendo, it was already noted that the power supply is one of the most important components of a power amplifier. In fact, the ultimate sound quality depends on the power supply. The design of a good power supply does not have to be difficult, since the well-known and commonly used formula of a transformer, bridge rectifier and electrolytic filter capacitors is fully adequate. However, you should not try to cut corners here, which is why two electrolytic capacitors of no less than 22,000 µF (22 mF) are used in the power supply shown in **Figure 3**. In order to avoid misunderstand-

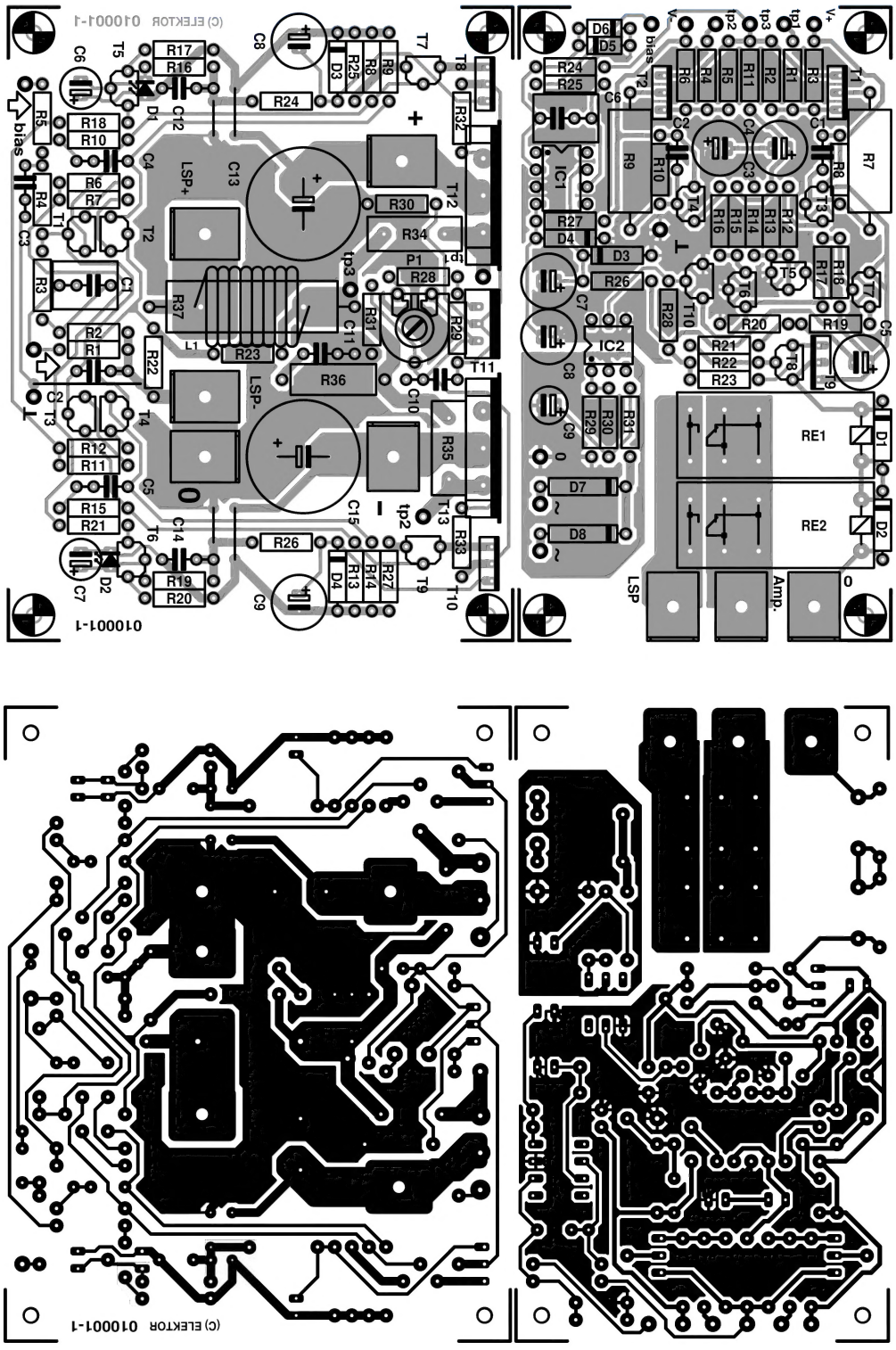


Figure 5. The printed circuit boards for the amplifier and the protection circuitry are delivered as a single board and must be sawn apart.

COMPONENTS LIST
Amplifier board

Resistors:
R1 = 1MΩ
R2 = 47kΩ
R3,R22 = 470Ω
R4,R5 = 1MΩ8
R6,R7,R11,R12 = 47Ω
R8,R9,R13,R14 = 1kΩ
R10,R15 = 330Ω
R16,R19,R30,R31 = 22kΩ
R17,R20,R28 = 270Ω
R18,R21 = 8kΩ2
R23 = 12kΩ
R24,R26 = 10kΩ
R25,R27 = 33Ω
R29 = 120Ω
R32,R33 = 220Ω
R34,R35 = 0Ω22 / 5W low-inductance, e.g., MPC71 series
R36 = 10Ω / 1W *
R37 = 1Ω / 5W
P1 = 1kΩ preset H

Capacitors:
C1 = 2µF2, MKT (Siemens), lead pitch 5mm or 7.5mm
C2,C4,C5 = 1nF
C3 = 180nF
C6,C7 = 100µF 25V radial
C8,C9 = 220µF 25V radial
C10,C12,C14 = 100nF
C11 = 10nF *
C13,C15 = 1000µF 63V radial

Inductors:
L1 = 9 turns 1.5 mm dia. ECW around R37, inside diameter 8 mm

Semiconductors:
D1,D2 = rectangular face, red
D3,D4 = zener diode 3V9 / 0.5W
T1,T2,T6 = BC546B
T3,T4,T5 = BC556B
T7 = BC560C
T8 = MJE350
T9 = BC550C
T10 = MJE340
T11 = 2SK537 (Toshiba)
T12 = 2SK1530 (Toshiba)
T13 = 2SJ201 (Toshiba)

Miscellaneous:
5 off M3 spade terminals, PCB mount
3 off ceramic (or mica) isolating washer for voor T8/T10/T11
2 off mica isolating washer for

ings, we hasten to point out that we are talking about a monaural version here, so for a stereo amplifier you will have to build two of these supplies!
The 'mains switch-on delay' shown inside the dotted box in Figure 3 is not mandatory, but it is highly recommended — especially if a toroidal transformer is used. This circuit does exactly what its name suggests, and it ensures that excessive current surges do not occur when the mains voltage is switched on. Such circuits have frequently been described in Elektor Electronics; the most recent one can be found in the Summer Circuits issue of 1997, and we have reproduced its

T12/T13 (e.g., TO-218 sheets size 21 x 24 mm)
Heatsink: < 0.5°K/W (e.g., Fischer type SK47/100 mm, Dau Components)
PCB, order code **010001-1**
Mainsd power-on delay PCB , order code **974078-1**
Enclosre, e.g., Monacor (Monarch) type UC113/SW

*) may be omitted

Protection board

Resistors:
R1,R4 = 390Ω
R2,R5 = 120Ω
R3,R6 = 18kΩ
R7,R9 = 1kΩ / 5W
R8,R10 = 5kΩ6
R11,R25,R30,R31 = 10kΩ
R12,R13,R24 = 1MΩ
R14 = 150kΩ
R15 = 39kΩ
R16,R20,R21 = 220kΩ
R17 = 330kΩ
R18 = 12kΩ
R19 = 330Ω
R22 = 15kΩ
R23 = 680Ω
R26,R27 = 4kΩ7
R28 = 470kΩ
R29 = 3kΩ3

Capacitors:
C1,C2 = 150pF
C3,C4 = 22µF 63V radial
C5 = 47µF 63V radial
C6 = 2µF2 MKT (Siemens), lead pitch 5mm or 7.5mm
C7,C8 = 220µF 25V radial
C9 = 1µF 63V radial

Semiconductors:
D1,D2 = 1N4148
D3,D4 = zender diode 20V / 0.5W
D5,D6 = BAT85
D7,D8 = 1N4004
T1 = MJE340
T2 = MJE350
T3,T8 = BC556B
T4,T5,T6,T10 = BC546B
T7 = BC516
T9 = BD140
IC1 = OP77GP (Analog Devices)
IC2 = CNY17-3

Miscellaneous:
Re1,Re2 = relay, type G2R-1-E (Omron), 16A / 24V / 1100 ohm)
3 off M3 spade terminal, PCB mount

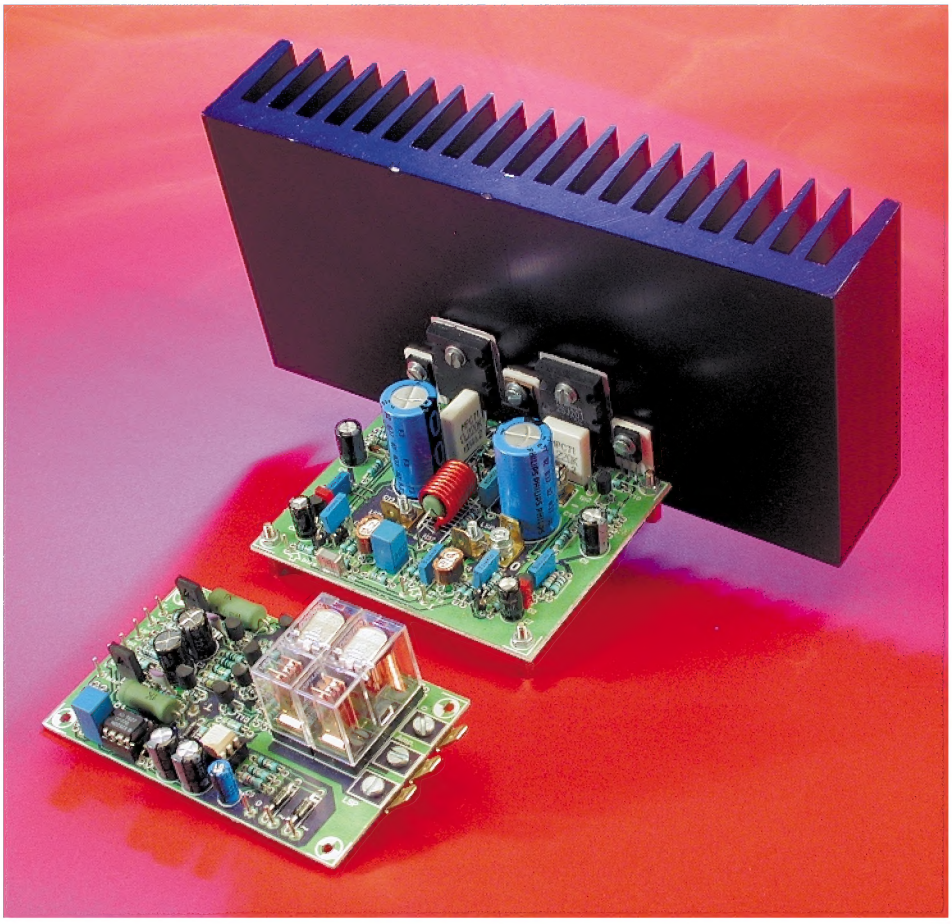


Figure 6. This is how the finished circuit board should appear. Don't forget the insulating washers for transistors T8 and T10–T13!

schematic diagram in **Figure 4**. Its operation is simple, and is based on the fact that the current is initially limited by R4-R7 immediately after switch-on. After the expiry of a time delay determined by C2 and C3, these resistors are bridged over by the relay and the full current flows between K1 and K2. The relay used here is a type that can switch 2000 VA. The supply voltage for the relay is taken directly from the mains circuit via C1, R3 and B1, so this circuit is dangerous to the touch!

Soldering

The printed circuit board layouts for the amplifier and protection circuitry are shown in **Figure 5**. These circuit boards are supplied as a single piece, so the must be (carefully) sawn apart. Experienced electronics types will not need very much advise with regard to the construction of the circuit boards, since the component layout overlay and the components list speak for themselves. Still, we would like to make a few practical remarks.

On the amplifier board, five wire bridges must be inserted, and it is a good idea to do this at the beginning. In addition, there are two items on the amplifier board that could be considered to be somewhat difficult: the thermal coupling and the output coil L1.
For the thermal coupling between the D1/T5 and D2/T6 pairs, it is sufficient to mount the LED so that it is in contact with the flat face of the transistor. In the case of the T1/T2 and T3/T4 transistor pairs, it is recommended to clamp a small metal ring around each pair. Incidentally, we have discovered that suitable rings can be made by sawing them from a piece of copper water pipe and then bending them into a suitable shape.
Coil L1 can be easily wound on an 8-mm drill bit. After this you can insert R37 into the coil and then solder both components to the circuit board, after having first removed the lacquer from the two ends of the coil with the aid of a knife.
Transistors T8 and T10–T13 are intentionally placed along one edge of the circuit board so that they can easily be screwed to a single common heat sink. Naturally, the transistors must be mounted using insulating washers,

and as usual it is recommended to smear a thin layer of thermal grease on each side of the insulator before mounting the transistor. The thermal resistance of the heat sink should be less than 0.5 K/W. **Figure 6** shows one of the fully assembled prototype amplifier circuit boards with attached heat sink.
There isn't much to say about the protection circuit board. You should pay attention to the diameter of the electrolytic capacitor C5, which must be no more than 8 mm. If you cannot obtain a suitable type, a 40-V type can also be used.
For the sake of completeness, the printed circuit board layout of the previously mentioned mains switch-on delay circuit is shown in **Figure 7**. This circuit board was never included in the Readers Services list in the past, but since this 'two-stage' delay can be especially useful for a variety of applications, we have now added it to the list.

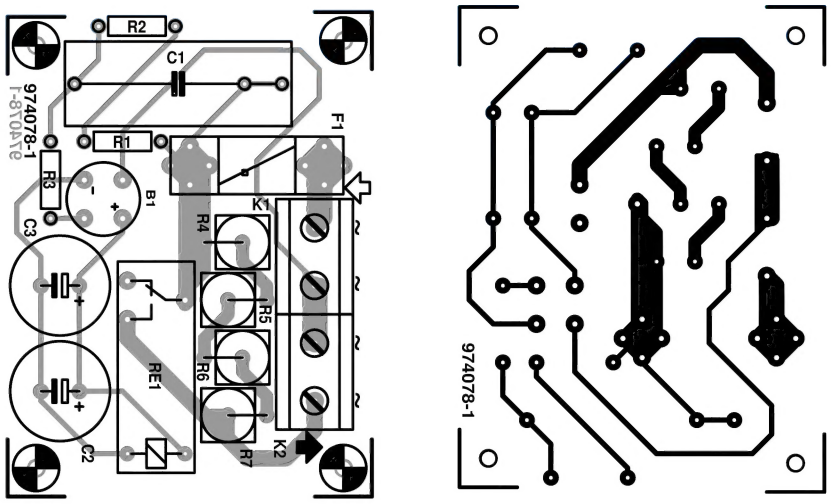


Figure 7. The printed circuit board layout for the mains switch-on delay circuit shown in Figure 4.

Wiring and set-up

Once you have finished building the amplifier and protection logic boards (or sets of boards) and have carefully checked them against the components list, it is time to start looking for a suitable enclosure. The first decision to be made is whether you want to build the amplifier as a monophonic building block or as a stereo version. We chose the latter option for our prototype, which means that what we actually did was to build two mono blocks into a single enclosure, each with its own power supply and mains switch-on delay. The only shared item is the mains switch. For the enclosure, we chose a Monacor (in some countries: Monarch) box that provides a generous amount of room for everything, and then mounted hefty heat sinks (bigger than actually required) on opposite sides of the box.
Since there are several circuit boards involved, the wiring of the complete amplifier includes quite a few interconnections – which is why we have made a separate wiring diagram, as shown in **Figure 8**. Connect the V+, V–, earth, tp1, tp2, tp3 and bias points on the protection board to the corresponding points on the amplifier board using ordinary insulated stranded wire. The '~35 V' points should be connected directly to the outer ends of the transformer windings, and point '0' should be connected to the junction of the filter capacitors in the power supply.
Use lengths of screened audio cable to make the connections between the input sockets (Cinch sockets) and the input points on the amplifier boards.
Flat tab connectors (automotive connectors) are used for the output and supply connections on the circuit boards. The connections between these points must naturally be made using heavy-gauge wiring. We used 2.5-mm^2 electrical wire for this purpose. The contacts of relays Re1 and Re2 on the protection board are simply connected in series with the amplifier output by connecting the output terminal 'LSP+' to the relay input terminal 'Amp' and the 'LSP' terminal of the protection board to the positive output socket (banana socket). The other (negative) banana socket is connected directly to the 'LSP–' terminal.
The necessary connection between the circuit ground of the amplifier and the metallic enclosure can best be realised by fitting the Cinch (a.k.a. RCA or 'line') input sockets in a 'normal' (non-insulated) manner. Take care that there is not any other unintentional connection between the signal ground and the enclosure ground, since this will create an earth loop that can cause stubborn hum problems.
It goes without saying that a well-insulated cable, a robust mains switch and an equally robust mains entrance must be used for the connection to the 230-V mains circuit. Pay attention to the electrical safety of the overall assembly, and attach an identification label that lists the specified values of the supply voltage (230 V) and fuse to the outside of the enclosure.

Once you have again thoroughly checked everything and re-measured the supply voltages, it's nearly time to power up the amplifier. Before doing this, however, you must turn trimpot P1 fully to the left (counter clockwise). Otherwise you run the risk that the quiescent current will immediately rise to a very high level, which is not what we want.
After switching on the unit, first check the amplifier output (test point tp3) to verify that the voltage is zero. An offset of a few millivolts is acceptable, but if you measure 0.1 V or more you will have to carefully reinspect the whole assembly, since there is something wrong.
Following this, you can set the quiescent current to the proper value. The ideal value for this amplifier is 200 to 250 mA. To adjust the quiescent current, connect a voltmeter across R34 (test points tp1 and tp3) and turn P1 slowly until the measured voltage is between 0.044 and 0.055 V. Then let the amplifier warm up for half an hour, and again adjust the current to the same value using P1.

Listening

Readers who have already taken a peek at the measurement results shown in the separate box will have quickly concluded that the Crescendo scores very well as far as the numbers are concerned. However, we know from experience that amplifiers with practically identical specifications can sound quite different.

We thus come to the crucial question: how good is the sound of the new amplifier (or, if you will, the 'refurbished old amplifier')?

The first thing that struck us in listening sessions is that the Crescendo can produce a nicely spacious and open sound image with all different types of music. Of course, the relative differences between good amplifiers are always very subtle, but the Crescendo clearly revealed itself to be an amplifier with a pleasantly warm-blooded character.

After listening to the amplifier for a while, we developed a certain understanding of the preferences of fervent MOSFET fans, since the sound produced by the amplifier is just a bit less reserved and clinical than that produced by a typical amplifier with bipolar transistors in the output stage. An amplifier such as the 'Compact AF Power Amplifier', which was published in May 1997 (and which is one of our favourites), offers reproduction that (according to our convictions) can hardly be surpassed in terms of natural fidelity and detailing, but it still misses that slight trace of warmth that is so typical of the Crescendo. Can we say that one of the two is the better amplifier? No, that would be going to far. The differences are too small for such a pronouncement, and anyhow such a judgement is always very subjective. 'Better' and 'worse' are qualifications that do not have a place here; at most we can say 'different'.

What well can be considered to be no less than amazing is that this Crescendo, in spite of (or thanks to) its simple concept and the age of the original design, can easily hold its own against many more modern examples of the breed. This amplifier can be highly recommended, and not only for MOSFET fans!

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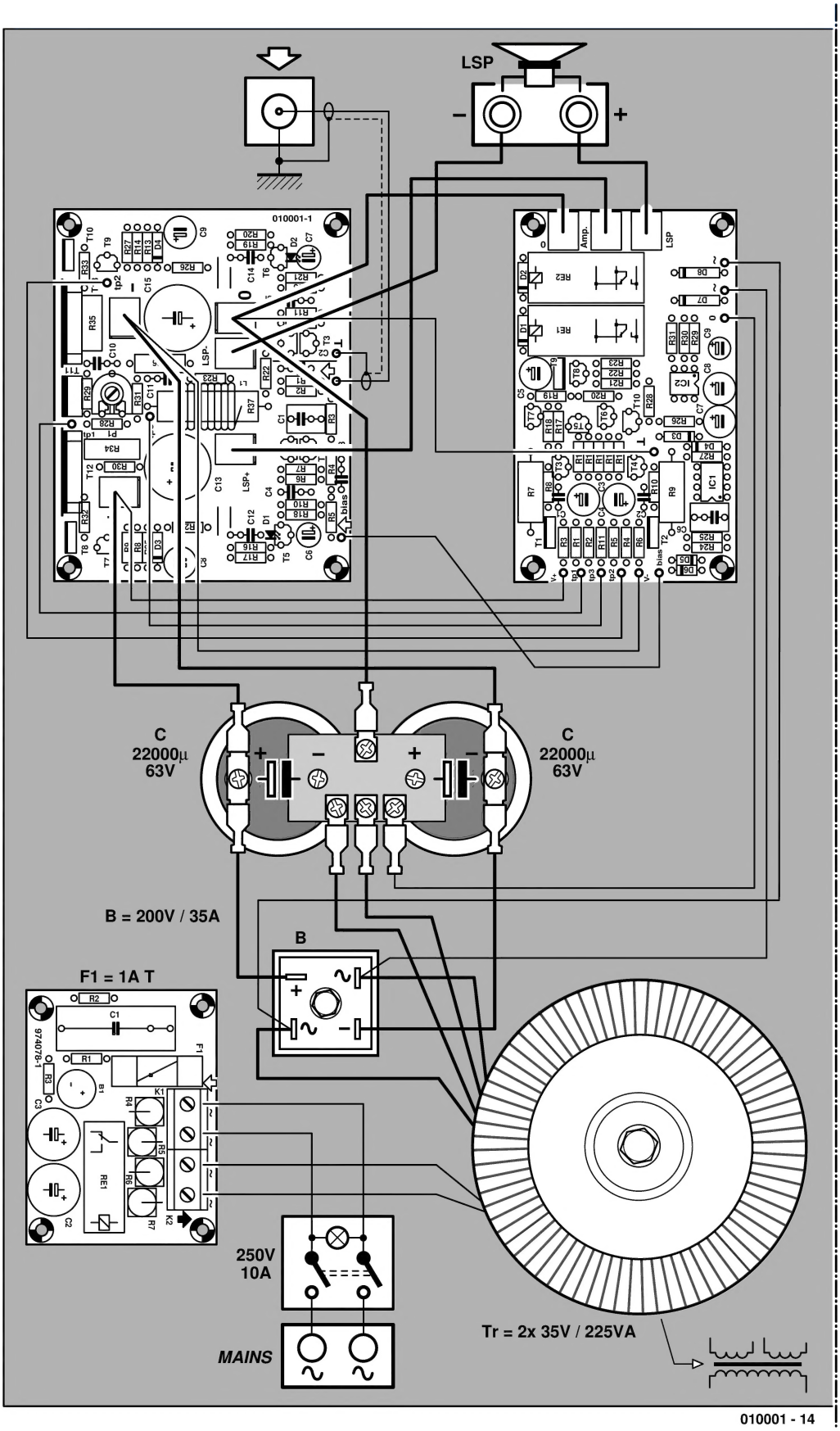

Figure 8. Wiring diagram. Thick wires must be used for the power supply and amplifier output wiring!